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Sanjay et al.

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(54) **SELF-ADAPTIVE INVENTORY AND FIXTURE TRACKING**

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(51) **Int. Cl.**

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G06K 7/10	(2006.01)
G06K 17/00	(2006.01)
G01S 5/02	(2010.01)
G06K 19/077	(2006.01)
H04L 29/08	(2006.01)
H04W 4/80	(2018.01)
G06N 20/00	(2019.01)

(52) **U.S. Cl.**

CPC ***G06Q 10/087*** (2013.01); ***G06K 7/10386*** (2013.01); ***G06K 17/0022*** (2013.01); *G01S 5/0284* (2013.01); *G01S 5/0294* (2013.01); *G06K 19/077* (2013.01); *G06N 20/00* (2019.01); *H04L 67/12* (2013.01); *H04W 4/80* (2018.02)

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USPC 235/385

See application file for complete search history.

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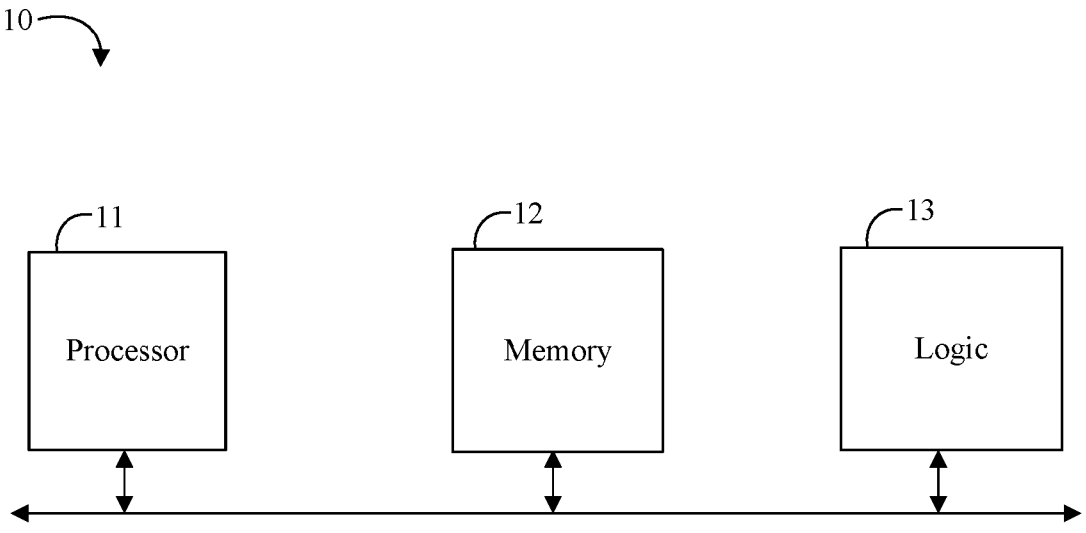
(57) **ABSTRACT**

An embodiment of a semiconductor package apparatus may include technology to associate an asset to a fixture with a device positioned proximate to the fixture, and determine a location of the fixture based on a location of the device. Other embodiments are disclosed and claimed. Non-limiting example applications may include shipping, logistics, warehouse asset tracking, retail, etc.

18 Claims, 10 Drawing Sheets



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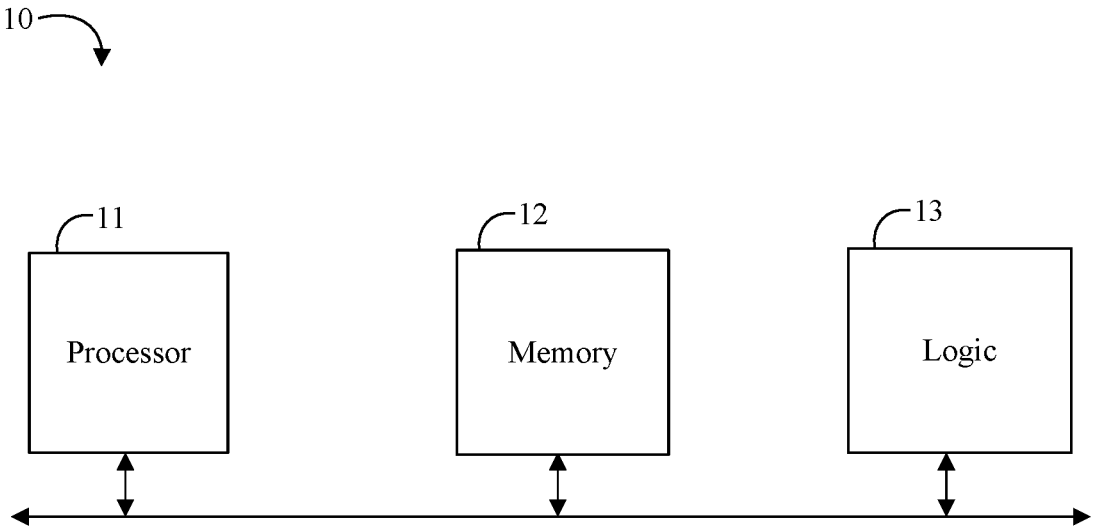


FIG. 1

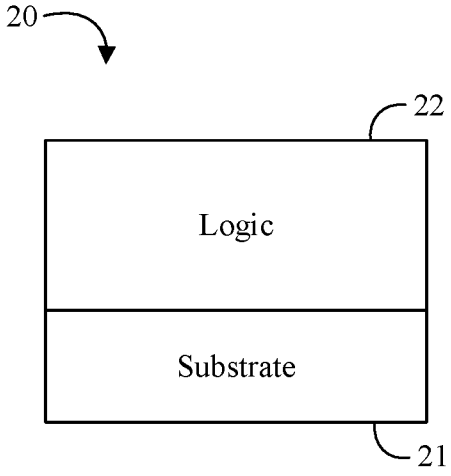


FIG. 2

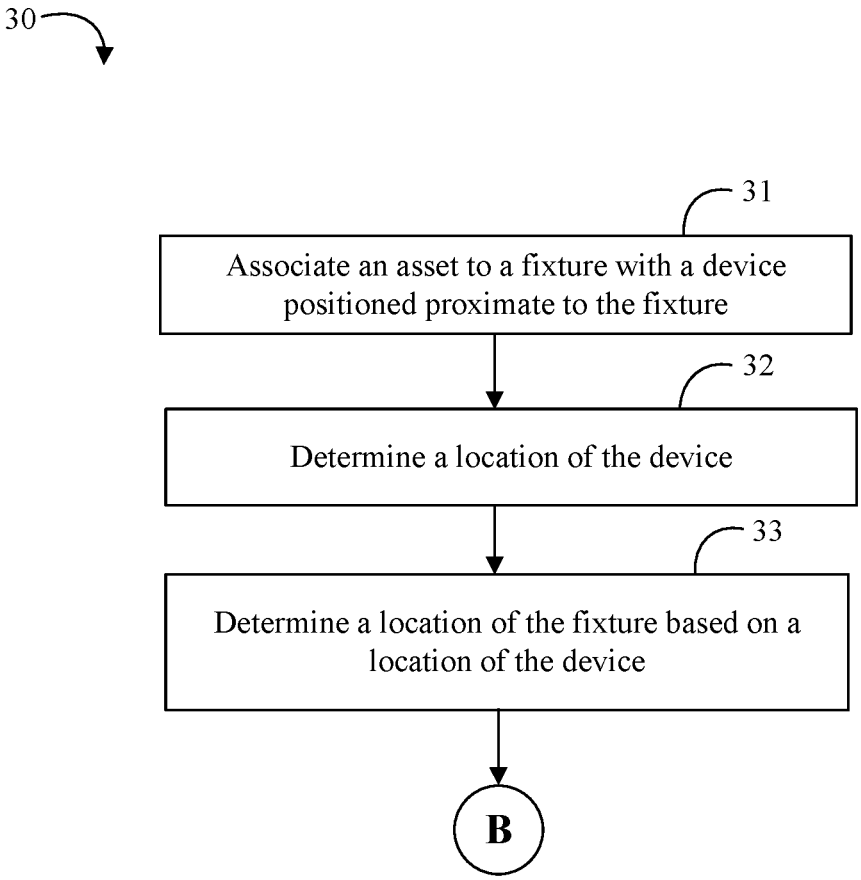

30
31
Associate an asset to a fixture with a device positioned proximate to the fixture
32
Determine a location of the device
33
Determine a location of the fixture based on a location of the device
B

FIG. 3A

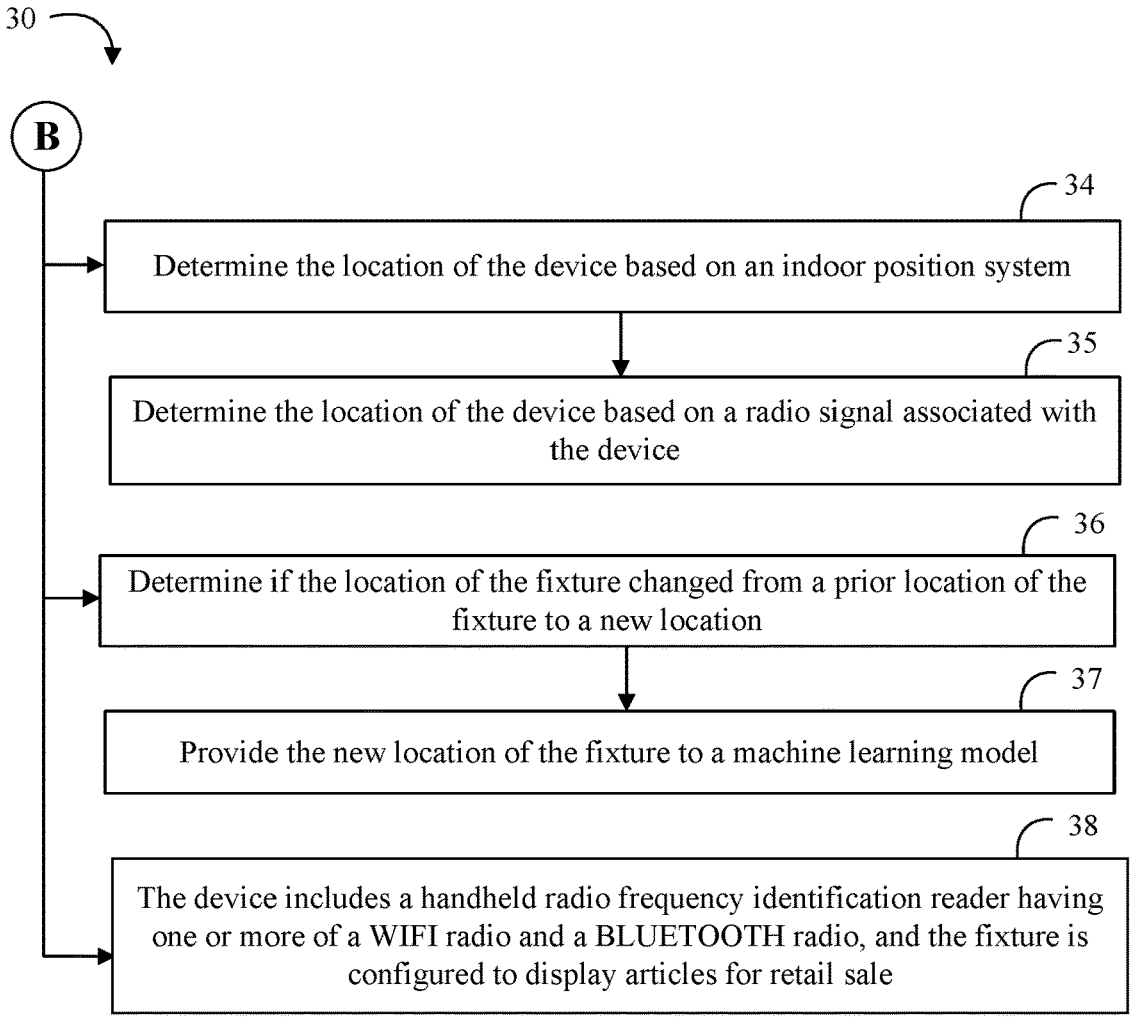

30
B
34
Determine the location of the device based on an indoor position system
35
Determine the location of the device based on a radio signal associated with the device
36
Determine if the location of the fixture changed from a prior location of the fixture to a new location
37
Provide the new location of the fixture to a machine learning model
38
The device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and the fixture is configured to display articles for retail sale

FIG. 3B

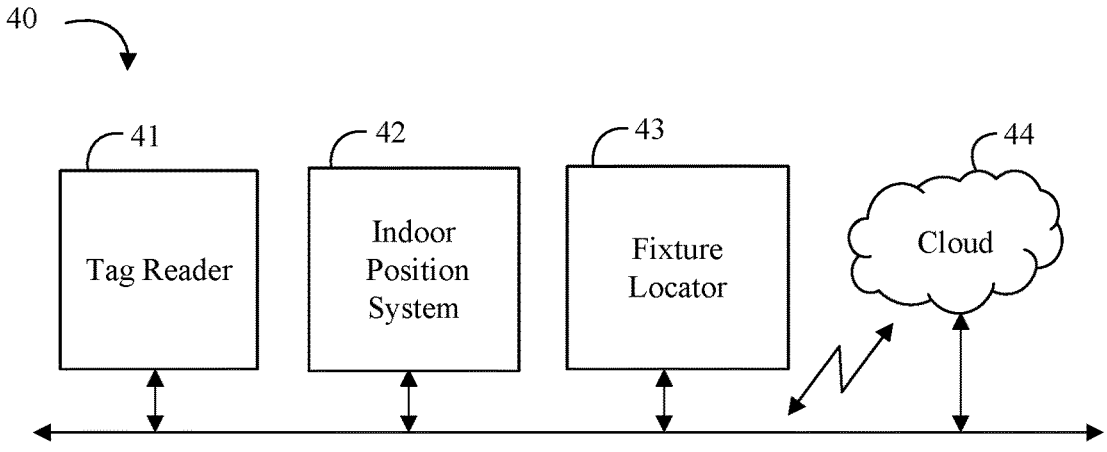
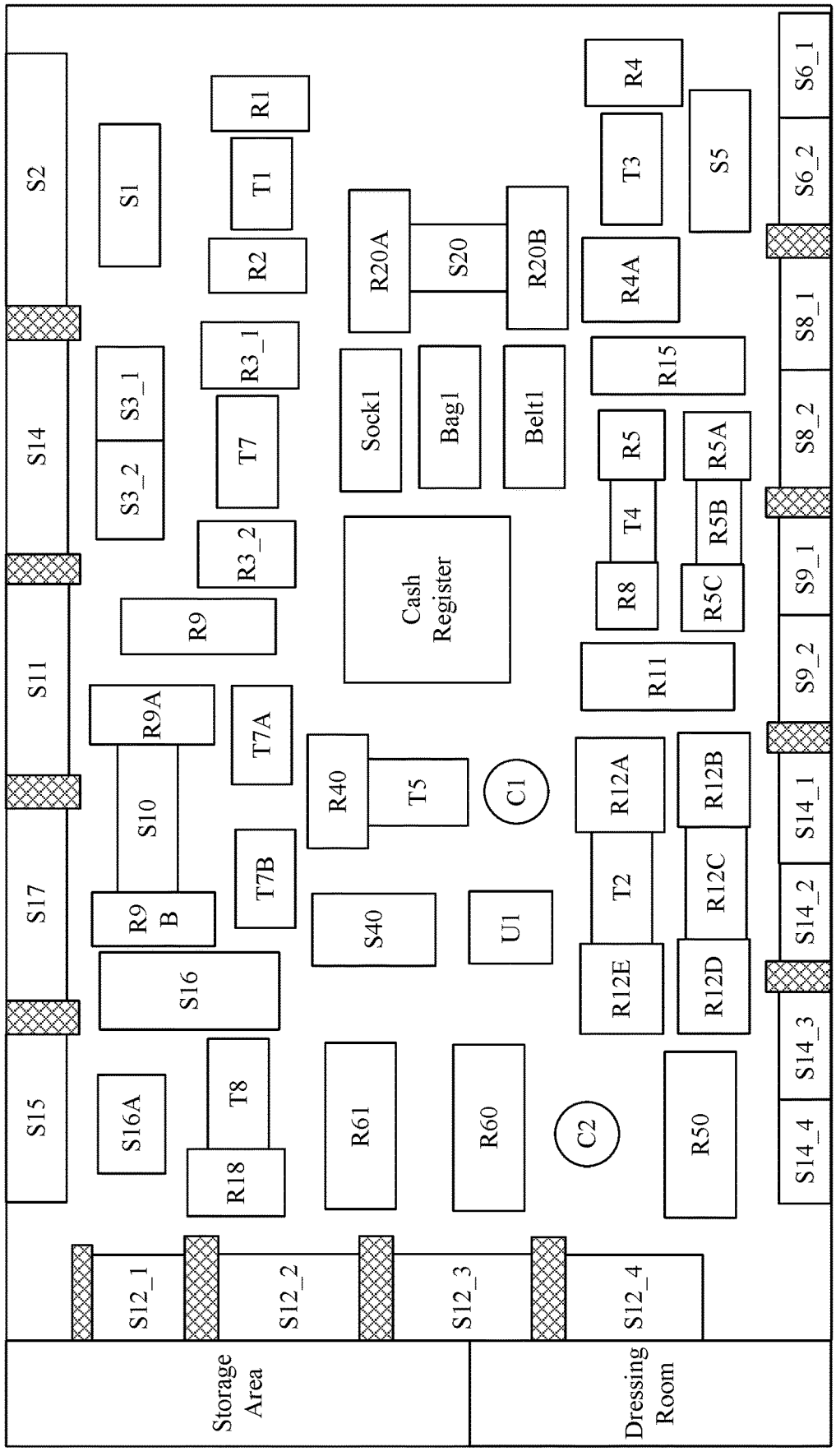

40
41
Tag Reader
42
Indoor Position System
43
Fixture Locator
44
Cloud

FIG. 4


S2
S1
R1
T1
R2
S3_1
S3_2
T7
R3_1
R3_2
R9
R9A
S10
R9B
T7A
T7B
S16
S16A
T8
R18
S15
S17
S11
S14
S12_1
S12_2
S12_3
S12_4
Storage Area
Dressing Room
R20A
S20
R20B
Sock1
Bag1
Belt1
Cash Register
R40
T5
C1
S40
U1
R61
R60
C2
R12A
T2
R12E
R12B
R12C
R12D
R50
R4
T3
R4A
R15
R5
R5A
T4
R5B
R8
R5C
R11
S5
S6_1
S6_2
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S8_2
S9_1
S9_2
S14_1
S14_2
S14_3
S14_4

FIG. 5

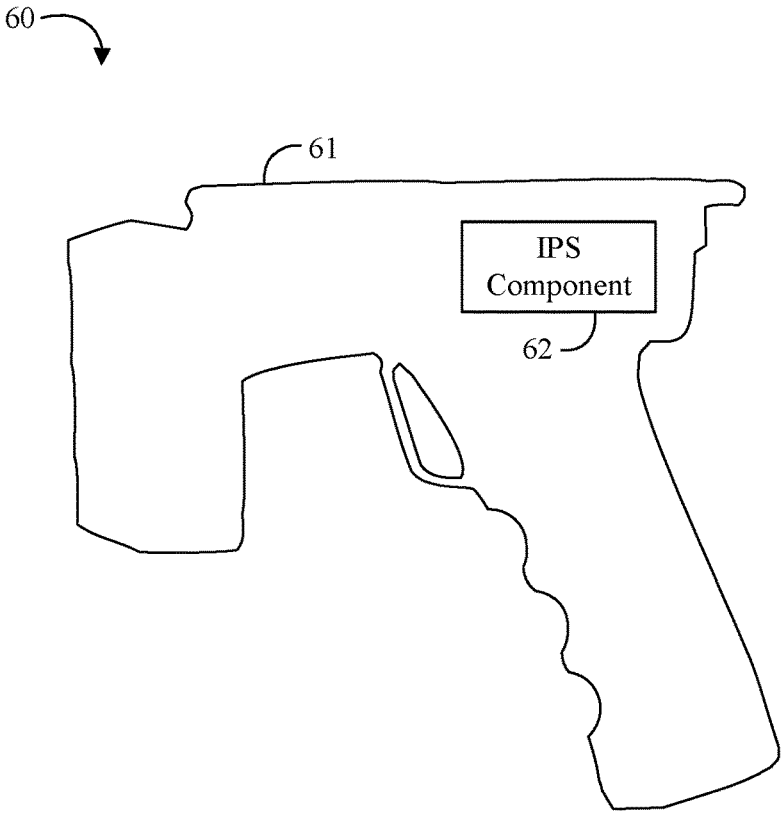

FIG. 6A

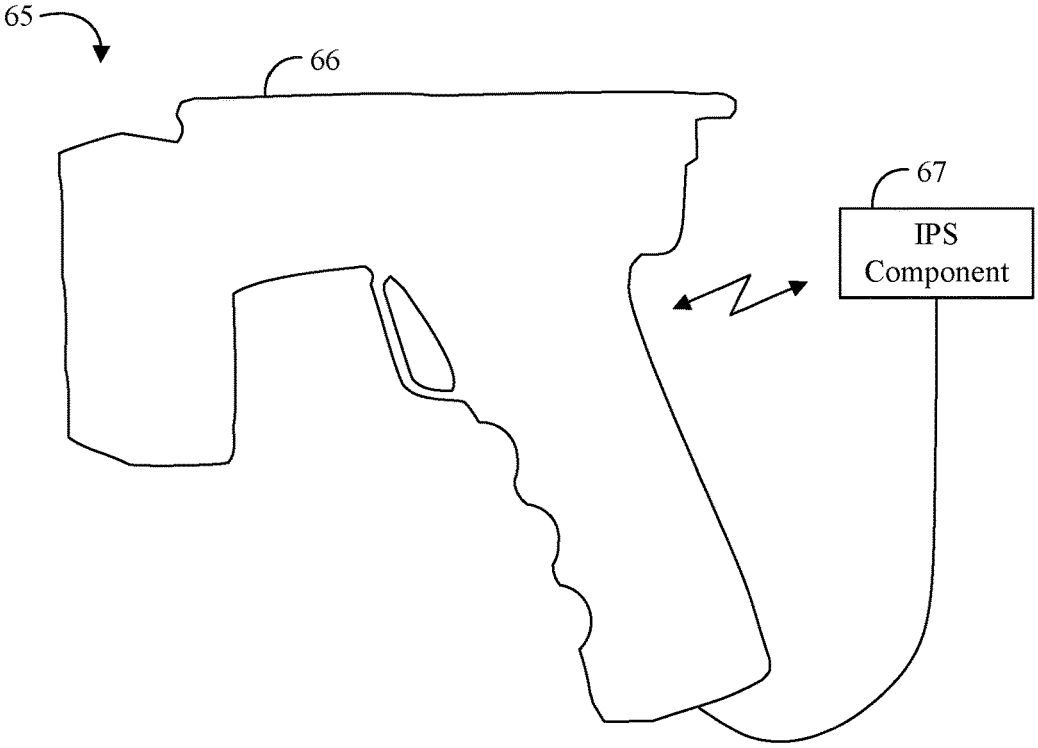

FIG. 6B

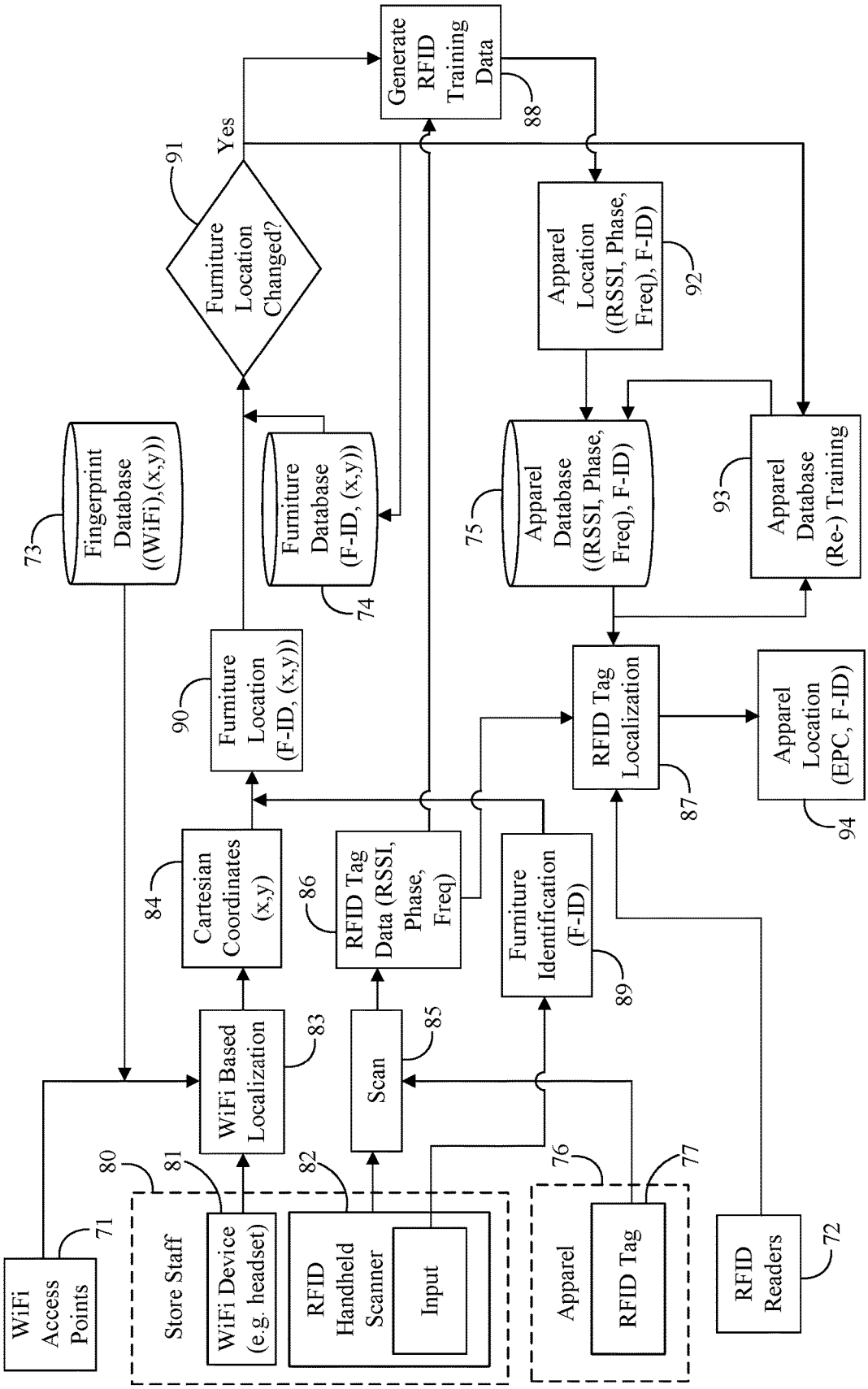
WiFi Access Points
71
Store Staff
80
WiFi Device (e.g. headset)
81
RFID Handheld Scanner
82
Input
Apparel
76
RFID Tag
77
RFID Readers
72
70
WiFi Based Localization
83
Scan
85
Cartesian Coordinates (x,y)
84
RFID Tag Data (RSSI, Phase, Freq)
86
Furniture Identification (F-ID)
89
Furniture Location (F-ID, (x,y))
90
RFID Tag Localization
87
Apparel Location (EPC, F-ID)
94
Fingerprint Database ((WiFi),(x,y))
73
Furniture Database (F-ID, (x,y))
74
Apparel Database ((RSSI, Phase, Freq), F-ID)
75
Apparel Database (Re-) Training
93
Furniture Location Changed?
91
Yes
Generate RFID Training Data
88
Apparel Location ((RSSI, Phase, Freq), F-ID)
92

FIG. 7

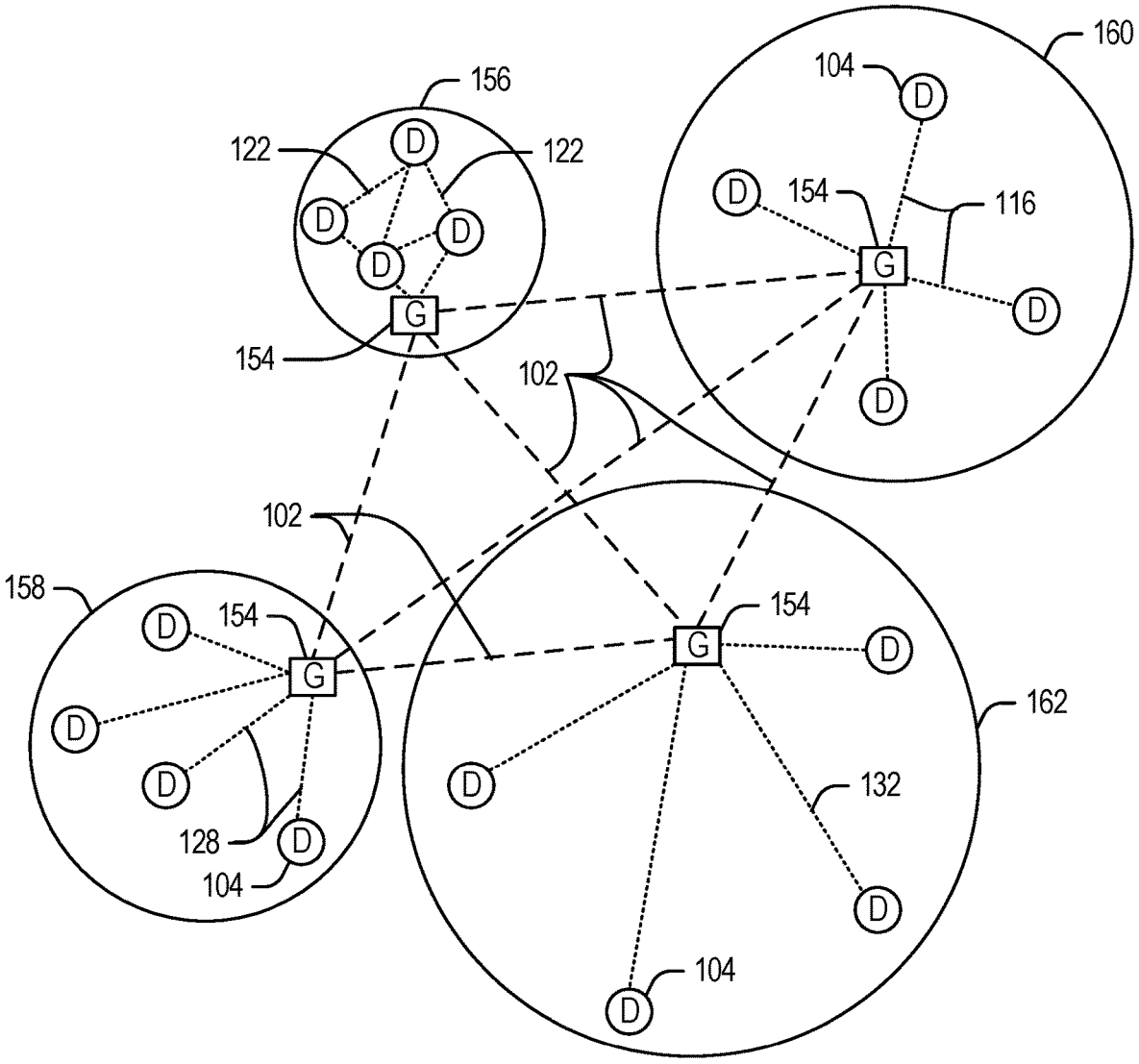
160
104
D
D
154
116
G
D
D
156
122
122
D
D
D
D
G
154
102
102
158
D
154
G
D
D
D
128
D
104
154
G
D
D
162
132
D
D
104
D

FIG. 8

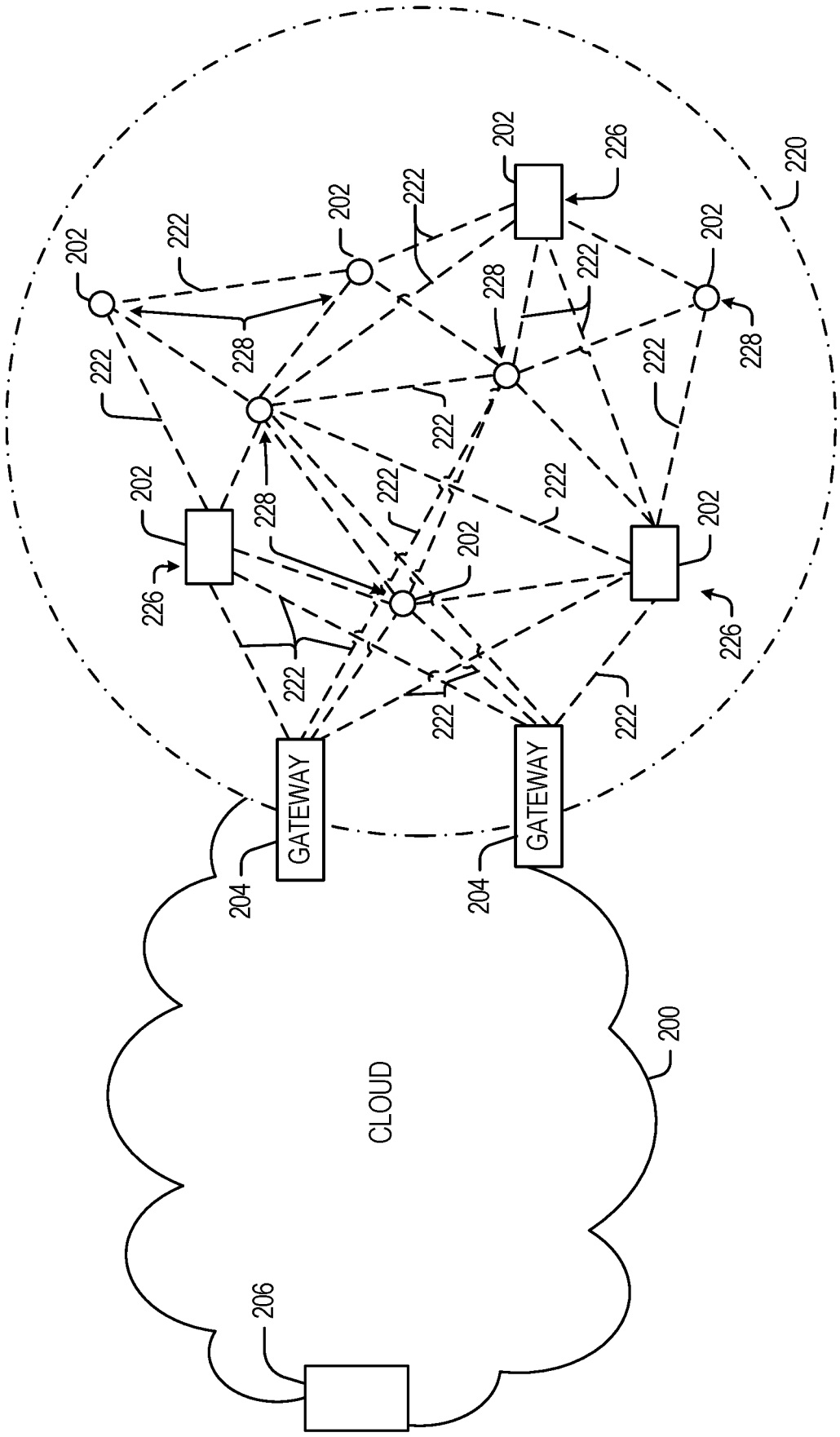

FIG. 9

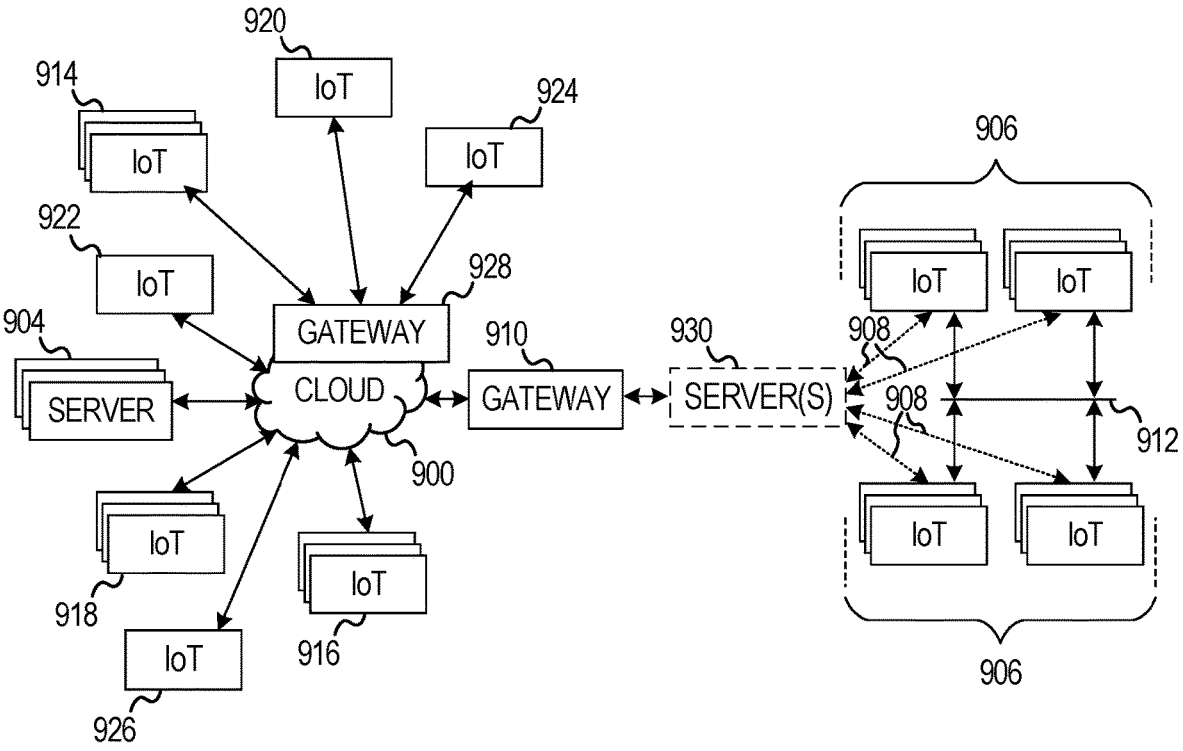
920
IoT
914
IoT
924
IoT
906
922
IoT
928
IoT
IoT
904
GATEWAY
910
930
908
SERVER
CLOUD
GATEWAY
SERVER(S)
908
912
900
IoT
IoT
IoT
918
IoT
916
906
926

FIG. 10

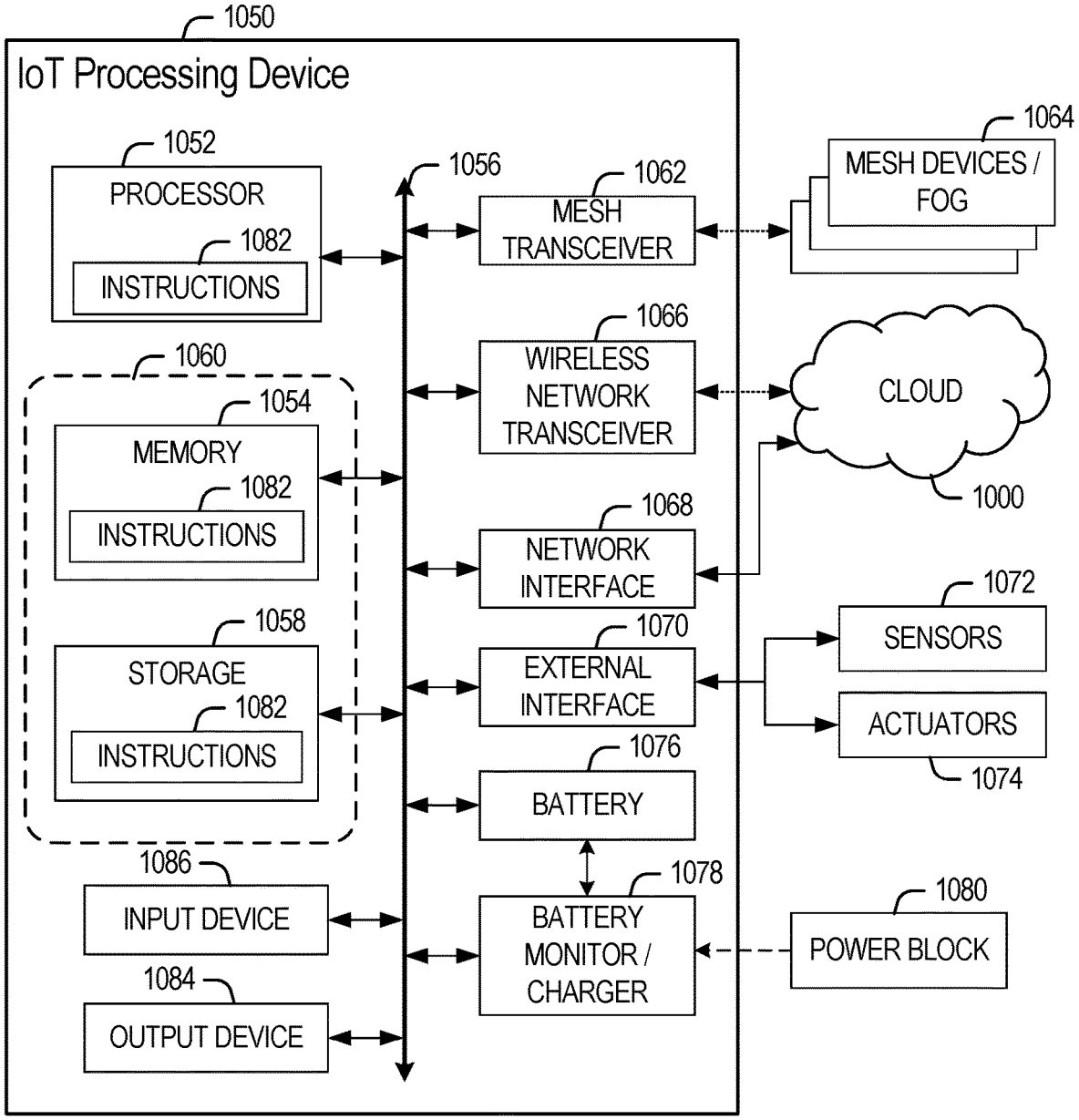
1050
IoT Processing Device
1052
PROCESSOR
1082
INSTRUCTIONS
1060
1054
MEMORY
1082
INSTRUCTIONS
1058
STORAGE
1082
INSTRUCTIONS
1086
INPUT DEVICE
1084
OUTPUT DEVICE
1056
1062
MESH TRANSCEIVER
1066
WIRELESS NETWORK TRANSCEIVER
1068
NETWORK INTERFACE
1070
EXTERNAL INTERFACE
1076
BATTERY
1078
BATTERY MONITOR / CHARGER
1064
MESH DEVICES / FOG
CLOUD
1000
1072
SENSORS
ACTUATORS
1074
1080
POWER BLOCK

FIG. 11

SELF-ADAPTIVE INVENTORY AND FIXTURE TRACKING

TECHNICAL FIELD

Embodiments generally relate to asset tracking. More particularly, embodiments relate to self-adaptive inventory and fixture tracking.

BACKGROUND

Asset tracking may useful for a wide variety of environments and applications. Non-limiting example environments/applications may include shipping, logistics, warehouse asset tracking, retail, etc. Some applications may use handheld scanners or readers to track inventory. In retail applications, articles for sale may include symbols or radio frequency identification (RFID) tags that may be recognized by such handheld scanners/readers.

Internet of things (IoT) devices are physical objects that may communicate on a network, and may include sensors, actuators, and other input/output components, such as to collect data or perform actions from a real world environment. For example, IoT devices may include low-powered devices that are embedded or attached to everyday things, such as buildings, vehicles, packages, etc., to provide an additional level of artificial sensory perception of those things. Recently, IoT devices have become more popular and thus applications using these devices have proliferated.

Various standards have been proposed to more effectively interconnect and operate IoT devices and IoT network use cases. These include the specialization of communication standards distributed by groups such as Institute of Electrical and Electronics Engineers (IEEE), and the specialization of application interaction architecture and configuration standards distributed by groups such as the Open Connectivity Foundation (OCF).

BRIEF DESCRIPTION OF THE DRAWINGS

The various advantages of the embodiments will become apparent to one skilled in the art by reading the following specification and appended claims, and by referencing the following drawings, in which:

FIG. **1** is a block diagram of an example of an electronic processing system according to an embodiment;

FIG. **2** is a block diagram of an example of a semiconductor package apparatus according to an embodiment;

FIGS. **3**A to **3**B are flowcharts of an example of a method of tracking a fixture according to an embodiment;

FIG. **4** is a block diagram of an example of a fixture tracker apparatus according to an embodiment;

FIG. **5** is an illustrative diagram of an example of a retail environment according to an embodiment;

FIG. **6**A is an illustrative diagram of an example of a fixture tracking system according to an embodiment;

FIG. **6**B is an illustrative diagram of another example of a fixture tracking system according to an embodiment;

FIG. **7** is a block diagram of an example of another electronic processing according to an embodiment;

FIG. **8** illustrates a domain topology for respective internet-of-things (IoT) networks coupled through links to respective gateways, according to an example;

FIG. **9** illustrates a cloud computing network in communication with a mesh network of IoT devices operating as a fog device at the edge of the cloud computing network, according to an example;

FIG. **10** illustrates a block diagram of a network illustrating communications among a number of IoT devices, according to an example; and

FIG. **11** illustrates a block diagram for an example IoT processing system architecture upon which any one or more of the techniques (e.g., operations, processes, methods, and methodologies) discussed herein may be performed, according to an example.

DESCRIPTION OF EMBODIMENTS

Turning now to FIG. **1**, an embodiment of an electronic processing system **10** may include a processor **11**, memory **12** communicatively coupled to the processor **11**, and logic **13** communicatively coupled to the processor **11** to associate an asset to a fixture with a device positioned proximate to the fixture, determine a location of the device, and determine a location of the fixture based on the location of the device. In some embodiments of the system **10**, the logic **13** may be configured to determine the location of the device based on an indoor position system. For example, the logic **13** may be configured to determine the location of the device based on a radio signal associated with the device. In some embodiments of the system **10**, the logic **13** may also be configured to determine if the location of the fixture changed from a prior location of the fixture to a new location. For example, the logic **13** may provide the new location of the fixture to a machine learning application. In some embodiments, the device may include a handheld RFID reader having one or more of a WIFI radio and a BLUETOOTH radio, and the fixture may be configured to display articles for retail sale. Other non-limiting example environments/applications for some embodiments may include shipping, logistics, warehouse asset tracking, etc.

In some embodiments, the system **10** may further include an indoor positioning system (IPS) to determine the location of the device. For example, the IPS may include a geometric arrangement with respect to the location of the fixture. In some embodiments, the IPS may be based on the relative locations of two or more fixtures, enabling the movement of fixtures to update the IPS. In some embodiments, the fixtures may be part of the IPS and the logic **13** may be configured to determine improved or optimal placement of the fixtures for wireless coverage of the system **10** to monitor the movement of the asset(s).

Embodiments of each of the above processor **11**, memory **12**, logic **13**, and other system components may be implemented in hardware, software, or any suitable combination thereof. For example, hardware implementations may include configurable logic such as, for example, programmable logic arrays (PLAs), field programmable gate arrays (FPGAs), complex programmable logic devices (CPLDs), or fixed-functionality logic hardware using circuit technology such as, for example, application specific integrated circuit (ASIC), complementary metal oxide semiconductor (CMOS) or transistor-transistor logic (TTL) technology, or any combination thereof.

Alternatively, or additionally, all or portions of these components may be implemented in one or more modules as a set of logic instructions stored in a machine- or computer-readable storage medium such as random access memory (RAM), read only memory (ROM), programmable ROM (PROM), firmware, flash memory, etc., to be executed by a processor or computing device. For example, computer program code to carry out the operations of the components may be written in any combination of one or more operating system (OS) applicable/appropriate programming lan-

guages, including an object-oriented programming language such as PYTHON, PERL, JAVA, SMALLTALK, C++, C# or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. For example, the memory **12**, persistent storage media, or other system memory may store a set of instructions which when executed by the processor **11** cause the system **10** to implement one or more components, features, or aspects of the system **10** (e.g., the logic **13**, associating an asset to a fixture with a device positioned proximate to the fixture, determining a location of the device, determining a location of the fixture based on the location of the device, etc.).

Turning now to FIG. **2**, an embodiment of a semiconductor package apparatus **20** may include a substrate **21**, and logic **22** coupled to the substrate, wherein the logic is at least partly implemented in one or more of configurable logic and fixed-functionality hardware logic. The logic **22** coupled to the substrate may be configured to associate an asset to a fixture with a device positioned proximate to the fixture, determine a location of the device, and determine a location of the fixture based on the location of the device. In some embodiments, the logic **22** may be configured to determine the location of the device based on an indoor position system. For example, the logic **22** may be configured to determine the location of the device based on a radio signal associated with the device. In some embodiments, the logic **22** may also be configured to determine if the location of the fixture changed from a prior location of the fixture to a new location. For example, the logic **22** may provide the new location of the fixture to a machine learning application. In some embodiments, the device may include a RFID reader having one or more of a WIFI radio and a BLUETOOTH radio, and the fixture may be configured to display articles for retail sale. Other non-limiting example environments/applications for some embodiments may include shipping, logistics, warehouse asset tracking, etc.

Embodiments of logic **22**, and other components of the apparatus **20**, may be implemented in hardware, software, or any combination thereof including at least a partial implementation in hardware. For example, hardware implementations may include configurable logic such as, for example, PLAs, FPGAs, CPLDs, or fixed-functionality logic hardware using circuit technology such as, for example, ASIC, CMOS, or TTL technology, or any combination thereof. Additionally, portions of these components may be implemented in one or more modules as a set of logic instructions stored in a machine- or computer-readable storage medium such as RAM, ROM, PROM, firmware, flash memory, etc., to be executed by a processor or computing device. For example, computer program code to carry out the operations of the components may be written in any combination of one or more OS applicable/appropriate programming languages, including an object-oriented programming language such as PYTHON, PERL, JAVA, SMALLTALK, C++, C# or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages.

Turning now to FIG. **3**, an embodiment of a method **30** of tracking a fixture may include associating an asset to a fixture with a device positioned proximate to the fixture at block **31**, determining a location of the device at block **32**, and determining a location of the fixture based on a location of the device at block **33**. Some embodiments of the method **30** may further include determining the location of the device based on an indoor position system at block **34**. For example, the method **30** may include determining the location of the device based on a radio signal associated with the device at block **35**. Some embodiments of the method **30** may also include determining if the location of the fixture changed from a prior location of the fixture to a new location at block **36**. For example, the method **30** may also include providing the new location of the fixture to a machine learning application at block **37**. In some embodiments of the method **30**, the device may include a handheld RFID reader having one or more of a WIFI radio and a BLUETOOTH radio, and the fixture may be configured to display articles for retail sale at block **38**. Other non-limiting example environments/applications for some embodiments of the method **30** may include shipping, logistics, warehouse asset tracking, etc.

Embodiments of the method **30** may be implemented in a system, apparatus, computer, device, etc., for example, such as those described herein. More particularly, hardware implementations of the method **30** may include configurable logic such as, for example, PLAs, FPGAs, CPLDs, or in fixed-functionality logic hardware using circuit technology such as, for example, ASIC, CMOS, or TTL technology, or any combination thereof. Alternatively, or additionally, the method **30** may be implemented in one or more modules as a set of logic instructions stored in a machine- or computer-readable storage medium such as RAM, ROM, PROM, firmware, flash memory, etc., to be executed by a processor or computing device. For example, computer program code to carry out the operations of the components may be written in any combination of one or more OS applicable/appropriate programming languages, including an object-oriented programming language such as PYTHON, PERL, JAVA, SMALLTALK, C++, C# or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages.

For example, the method **30** may be implemented on a computer readable medium as described in connection with Examples 21 to 26 below. Embodiments or portions of the method **30** may be implemented in applications (e.g., through an application programming interface (API)) or driver software running on an operating system (OS).

Turning now to FIG. **4**, some embodiments may be logically or physically arranged as one or more modules. For example, an embodiment of a fixture tracker **40** may include a tag reader **41**, an indoor position system **42**, and a fixture locator **43**. For example, the tag reader **41** may associate an asset to a fixture (e.g., where the tag reader **41** is positioned proximate to the fixture). The indoor position system **42** may determine a location of the tag reader **41**. The fixture locator **43** may determine a location of the fixture based on the location of the tag reader **41** (e.g., from the indoor position system **42**). For example, the indoor position system **42** may be configured to determine the location of the tag reader **41** based on a radio signal associated with the tag reader **41**. In some embodiments, the fixture tracker **40** may also be configured to determine if the location of the fixture changed from a prior location of the fixture to a new location. For example, the fixture tracker **40** may provide the new location of the fixture to a machine learning application. In some embodiments, the tag reader **41** may include a RFID reader having one or more of a WIFI radio and a BLUETOOTH radio, and the fixture may be configured to display articles for retail sale. Other non-limiting example environments/applications for some embodiments may include shipping, logistics, warehouse asset tracking, etc.

The fixture tracker **40** may also include a connection to the cloud **44**. The cloud connection may be wired, wireless, or a hybrid combination thereof. For example, one or more

network nodes may be wired with electrically conducting or optical connections. For example, various databases or information originating from or useful to the tag reader **41**, the indoor position system **42**, and/or the fixture locator **43** may be located in the cloud **44** or maintained/provided by a cloud service. In some embodiments, the fixture tracker **40** may provide updates to fixture locations to a cloud service which maintains the machine learning application. The cloud service may train/retrain the machine learning model based on information received from the fixture tracker **40** and provide subsequent cloud services to the fixture tracker **40**.

Embodiments of the tag reader **41**, the indoor position system **42**, the fixture locator **43**, cloud **44**, and other components of the fixture tracker **40**, may be implemented in hardware, software, or any combination thereof including at least a partial implementation in hardware. For example, hardware implementations may include configurable logic such as, for example, PLAs, FPGAs, CPLDs, or fixed-functionality logic hardware using circuit technology such as, for example, ASIC, CMOS, or TTL technology, or any combination thereof. Additionally, portions of these components may be implemented in one or more modules as a set of logic instructions stored in a machine- or computer-readable storage medium such as RAM, ROM, PROM, firmware, flash memory, etc., to be executed by a processor or computing device. For example, computer program code to carry out the operations of the components may be written in any combination of one or more OS applicable/appropriate programming languages, including an object-oriented programming language such as PYTHON, PERL, JAVA, SMALLTALK, C++, C# or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages.

Some embodiments may advantageously provide self-adaptive machine-learning based inventory tracking with automated training data collection. Indoor location technology may deliver location-based services. For example, an indoor IPS may locate devices, objects, and/or people inside a building using radio waves, optical signals, machine vision, magnetic fields, acoustic signals, and/or other sensory information. The IPS may include, for example, a grid system or some other geometric arrangement. Machine learning based location tracking may improve the robustness of an IPS against outliers and non-linearity (e.g., utilizing neural networks and/or random forests). A problem for machine learning applications, however, is that the infrastructure may change from time to time. For example, in a brick-and-mortar retailer the display locations may be defined by various furniture locations which may change from time to time (e.g., on a weekly basis or even more frequently in some retail environments). Warehouse infrastructure may also change from time to time. The change in infrastructure may break down an existing machine learning application and require reacquisition of training data (e.g., labeled training data). In other systems, the infrastructure relabeling is supervised (e.g., requiring manual intervention). Advantageously, some embodiments may automate the collection of the training data and automatically update the machine learning application.

Turning now to FIG. **5**, an example layout of a retail environment may include many shelves (e.g., identified with a leading "S"), tables (e.g., identified with a leading "T"), racks (e.g., identified with a leading "R"), circular racks (e.g., identified with a leading "C"), and other retail display fixtures. The retail environment may also include one or more cash registers (e.g., or other point-of-sale kiosks, dressing rooms, and storage areas). Machine learning based applications may define clothing locations by corresponding locations of furniture holding or displaying the clothes (e.g., shelf, table, rack, etc.). If the location of any furniture changes, the machine learning based location tracking model may need to be retrained. Advantageously, some embodiments may collect the ground truth labeled data in an unsupervised manner (e.g., with little or no additional human efforts). Although described in connection with inventory tracking in a retail environment, some embodiments may be applied to other asset tracking applications including, for example, warehouse logistics, corporate asset tracking, etc.

Turning now to FIG. **6**A, an embodiment of a fixture tracking system **60** may include a handheld reader **61** with an integrated IPS component **62**. The reader **61** may include any useful asset tracking device such as an optical scanner, an RFID reader, a BLUETOOTH LOW ENERGY (BLE) reader, a NEAR FIELD COMMUNICATION reader (NFC), etc., to read a tag or symbol affixed to or associated with an asset (e.g., an article for sale). The integrated IPS component **62** may include any useful beacon, circuit, device, or component which aids the IPS in locating the position of the IPS component **62** (e.g., and also the location of the handheld reader **61** by its association with the IPS component **62**). For example, the IPS component **62** may include a WIFI radio, a BLUETOOTH radio, IBEACON technology, etc. Non-radio technologies including, for example, magnetic positioning technology, inertial positioning technology, visual positioning technology may also be utilized. For magnetic positioning, for example, the IPS component **62** may include an electronic compass component. For inertial positioning, for example, the IPS component **62** may include an inertial measurement unit (IMU). For visual positioning, for example, the IPS component **62** may include a camera to capture images of visual markers. The IPS component **62** may be used by other functions of the handheld reader **61** for other purposes. For example, if the IPS component **62** includes a radio component the radio may be used for communication purposes in addition to positioning purposes.

Turning now to FIG. **6**B, an embodiment of a fixture tracking system **65** may include a handheld reader **66** with an external IPS component **67**. The reader **66** may include any useful asset tracking device, such as those described elsewhere herein. The integrated IPS component **67** may include any useful beacon, circuit, device, or component which aids the IPS in locating the position of the IPS component **67**, such as those described elsewhere herein. When the IPS component is integrated with the reader (e.g., as shown in FIG. **6**A), the location of the IPS component may be considered as a direct proxy for the location of the reader. For the fixture tracking system **65**, however, the IPS component **67** may be external to the reader **66**. For example, the IPS component **67** may be included in a laptop, a tablet device, a smartphone, or some other electronic device (e.g., a device carried by the user of the reader **66**) that is paired with or otherwise associated with the reader **66** (e.g., either wired, wirelessly, or a combination thereof). Additionally, or alternatively, the user of the handheld reader **66** may wear a headset (e.g., a BLUETOOTH headset) or other wearable device that is paired or otherwise associated with the reader **66**. In this manner, some embodiments may use the location of the external IPS component **67** as an indirect proxy for the location of the reader **66**. Such pairings or associations may be configurable and/or may change from time to time.

Some embodiments may advantageously utilize an out-of-band signal for indoor positioning such as, for example, WIFI fingerprinting (e.g., with a 1-2 meter accuracy) and/or ultra wideband (UWB) trilateration (e.g., with a 20 centimeter accuracy). For example, a handheld RFID reader may include a BLUETOOTH subsystem (e.g., and/or a WIFI subsystem) which may be readily paired with other handheld or wearable devices (e.g., a tablet and/or a headset) which may also include other radio technologies which may be useful for WIFI fingerprinting, UWB trilateration, triangulation, triangulateration, etc. In accordance with some embodiments, such radio technology may be utilized to determine the location of a handheld RFID reader.

During inventory tracking, the store staff may use a handheld reader (e.g., as described in connection with FIGS. **6**A to **6**B), to scan each article upon moving it over from one place to another. For example, when a pair of jeans with apparel ID of Jeans-1 is placed on Rack-1, the store staff will scan the jeans and enter the furniture identification of Rack-1 to create a tuple of [Jeans-1, Rack-1]. The store staff may manually enter the furniture identification, or the furniture itself may include a symbol or tag that provides the appropriate identification. For example, the user may first scan the jeans and then the rack to create the tuple of [Jeans-1, Rack-1]. Alternatively, when multiple articles are being relocated, the user may first scan the rack and then each article that is being placed on the rack to efficiently create multiple tuples ([Jeans-1, Rack-1], [Jeans-2, Rack-1], [Jeans-N, Rack-1]). In any event, a typical inventory tracking process may allow the store staff to be able to collect an ordered set of values (e.g., tuples) of [Apparel-ID, Furniture-ID]. Advantageously, with little or no additional manual effort, some embodiments may determine the location of the fixtures based on the locations of the readers during the inventory process.

As noted previously, some embodiments may provide automated collection of labeled training data for asset tracking. For example, upon any collection by the store staff of a tuple [Apparel-ID, F=Furniture-ID], the location of the furniture may be determined based on a measurement R of the location of the RFID reader. The location of the RFID may be considered a reasonable approximation for the location of the furniture because it may be reasonable to assume that the user is near or proximate to the furniture when they scan the RFID tag (e.g., or the user's may be trained to always be near the furniture holding the articles when they perform asset inventory). Likewise, if the IPS component is not integrated with the RFID reader, the location of the IPS component may be considered as a reasonable approximation for the location of the reader, user, and/or furniture. In some embodiments, multiple RFID location measurements may be aggregated to determine the location of the furniture. For example, as the user moves along a wide shelf the IPS component location may vary even though the Furniture-ID does not. Similarly, as the user moves around a circular rack the multiple location measurements may help indicate the center of the circular rack location and the size of the circular rack. In some embodiments, RFID reader/IPS component locations from multiple users may be aggregated as well (e.g., a first user scans an RFID tag near one end of shelf, a second user scans an RFID tag near another end or the middle of the shelf, etc.).

If the furniture location is determined to have changed, the tuples along with the corresponding measurements R from the RFID readers may later be used for retraining a new machine learning application. Advantageously, the tuples of [Apparel-ID, F=Furniture-ID] may be collected automatically in the retail inventory tracking process, and the location change may be detected automatically using an out-of-band indoor positioning technology. Accordingly, some embodiments may provide online adaptiveness and/or reduced or minimized additional human efforts.

Some embodiments may utilize machine learning for asset tracking. For example, the collection of tuples of [Apparel-ID, F=Furniture-ID], along with the corresponding measurements R from a collection of RFID readers, may serve as the input to a supervised machine learning method for asset tracking. Some machine learning applications may learn the relationship between R and F and may predict F given R. For example, the furniture location may define the measurements R of apparel when the apparel sits on the furniture, based on the tuple [Apparel-ID, Furniture-ID]. Upon location changes of any furniture, the machine learning application may be retrained with a newly collected dataset in the new furniture setting. Some embodiments may immediately initiate such retraining upon any detected furniture location change, while some embodiments may initiate such retraining periodically, on a schedule, or based on other criteria (e.g., after N changes in location).

Turning now to FIG. **7**, an electronic processing system **70** may include one or more WIFI access points **71** and one or more RFID readers **72**. The system **70** may include multiple databases including a fingerprint database **73**, a furniture database **74**, and an apparel database **75**. Apparel **76** may be associated with or have RFID tags **77** affixed on the apparel **76**. The store staff **80** may wear or carry a WIFI device **81** and may also carry a handheld RFID reader **82**. An IPS may include WIFI based localization **83** to provide a set of Cartesian coordinates (x, y) **84** for the WIFI device **81** (e.g., using the fingerprint database **73**). When the store staff **80** performs a scan **85** of an RFID tag **77**, RFID tag data **86** (e.g., received signal strength indication (RSSI), phase, frequency, etc.) may be used for RFID tag localization **87** and to generate RFID training data **88**.

The store staff may also scan or otherwise input the furniture identification (F-ID) **89** and the Cartesian coordinates (x, y) **84** of the WIFI device **81** may be used as a proxy for the furniture location **90** (e.g., creating a tuple of [F-ID, (x, y)]). The furniture location **90** may be compared with the furniture database **74** to determine if the furniture location changed at **91**. For example, the furniture database **74** may initially include null data for the furniture location for each F-ID such that the determination at **91** may trigger the initial generation of RFID training data **88**. Subsequently, changes in the furniture location **90** may trigger retraining. The RFID training data **88** may be used to determine the apparel location **92** (e.g., [RFID data, F-ID]), while changes in the furniture location at **91** may trigger an apparel database retraining **93**. The RFID tag localization **87** may pull information from the apparel database **75** to determine the apparel location **94** (e.g., creating a tuple of [electronic product code (EPC), F-ID]).

In the system **70**, RFID technology may be a non-limiting example for machine learning based asset tracking and WIFI technology may be a non-limiting example of a beacon for continuous indoor positioning. Other tracking and/or radio/IPS technologies may be used in other embodiments. The apparel database (re-)training **93** may be performed immediately anytime when furniture location changed or scheduled on a regular basis, depending on whichever makes more sense in a given use case. Some embodiments may advantageously utilize an out-of-band localization technology to reinforce machine learning based applications for precision asset tracking by automating collection of labeled training

data. Some embodiments may be seamlessly integrated into inventory tracking of any brick-and-mortar retailers with little or no additional human efforts. In a retail environment where users scan each article upon moving the article, for example, some embodiments may provide self-adapting model reinforcement. For example, the process to collect ground truth labeled data may not require any additional supervision in addition to a typical retail inventory tracking process.

Additionally, or alternatively, some embodiments may advantageously provide online adaptiveness because the machine learning based application for precision asset tracking may be relatively more unsupervised because an infrastructure change may automatically trigger recollection of training datasets in order to retrain the machine learning application. Some embodiments may enable robust, precision location sensing, and sustainable location-based services with reduced deployment cost/efforts. Various embodiments may be implemented with any suitable electronics/computer technology including, for example, laptops, tablets, smartphones, handheld devices, and wearable devices. Many of the embodiments described herein include wireless components. In some embodiments, however, one or more such components may alternatively, or additionally, include wired connections such as electrically conducting wires or optical connections.

FIG. **8** illustrates an example domain topology for respective internet-of-things (IoT) networks coupled through links to respective gateways. The internet of things (IoT) is a concept in which a large number of computing devices are interconnected to each other and to the Internet to provide functionality and data acquisition at very low levels. Thus, as used herein, an IoT device may include a semiautonomous device performing a function, such as sensing or control, among others, in communication with other IoT devices and a wider network, such as the Internet.

Often, IoT devices are limited in memory, size, or functionality, allowing larger numbers to be deployed for a similar cost to smaller numbers of larger devices. However, an IoT device may be a smart phone, laptop, tablet, or PC, or other larger device. Further, an IoT device may be a virtual device, such as an application on a smart phone or other computing device. IoT devices may include IoT gateways, used to couple IoT devices to other IoT devices and to cloud applications, for data storage, process control, and the like.

Networks of IoT devices may include commercial and home automation devices, such as water distribution systems, electric power distribution systems, pipeline control systems, plant control systems, light switches, thermostats, locks, cameras, alarms, motion sensors, and the like. The IoT devices may be accessible through remote computers, servers, and other systems, for example, to control systems or access data.

The future growth of the Internet and like networks may involve very large numbers of IoT devices. Accordingly, in the context of the techniques discussed herein, a number of innovations for such future networking will address the need for all these layers to grow unhindered, to discover and make accessible connected resources, and to support the ability to hide and compartmentalize connected resources. Any number of network protocols and communications standards may be used, wherein each protocol and standard is designed to address specific objectives. Further, the protocols are part of the fabric supporting human accessible services that operate regardless of location, time or space. The innovations include service delivery and associated infrastructure, such as hardware and software; security enhancements; and the provision of services based on Quality of Service (QoS) terms specified in service level and service delivery agreements. As will be understood, the use of IoT devices and networks, such as those introduced in FIGS. **8** and **9**, present a number of new challenges in a heterogeneous network of connectivity comprising a combination of wired and wireless technologies.

FIG. **8** specifically provides a simplified drawing of a domain topology that may be used for a number of internet-of-things (IoT) networks comprising IoT devices **104**, with the IoT networks **156**, **158**, **160**, **162**, coupled through backbone links **102** to respective gateways **154**. For example, a number of IoT devices **104** may communicate with a gateway **154**, and with each other through the gateway **154**. To simplify the drawing, not every IoT device **104**, or communications link (e.g., link **116**, **122**, **128**, or **132**) is labeled. The backbone links **102** may include any number of wired or wireless technologies, including optical networks, and may be part of a local area network (LAN), a wide area network (WAN), or the Internet. Additionally, such communication links facilitate optical signal paths among both IoT devices **104** and gateways **154**, including the use of MUXing/deMUXing components that facilitate interconnection of the various devices.

The network topology may include any number of types of IoT networks, such as a mesh network provided with the network **156** using Bluetooth low energy (BLE) links **122**. Other types of IoT networks that may be present include a wireless local area network (WLAN) network **158** used to communicate with IoT devices **104** through IEEE 802.11 (Wi-Fi®) links **128**, a cellular network **160** used to communicate with IoT devices **104** through an LTE/LTE-A (4G) or 5G cellular network, and a low-power wide area (LPWA) network **162**, for example, a LPWA network compatible with the LoRaWan specification promulgated by the LoRa alliance, or a IPv6 over Low Power Wide-Area Networks (LPWAN) network compatible with a specification promulgated by the Internet Engineering Task Force (IETF). Further, the respective IoT networks may communicate with an outside network provider (e.g., a tier 2 or tier 3 provider) using any number of communications links, such as an LTE cellular link, an LPWA link, or a link based on the IEEE 802.15.4 standard, such as Zigbee®. The respective IoT networks may also operate with use of a variety of network and internet application protocols such as Constrained Application Protocol (CoAP). The respective IoT networks may also be integrated with coordinator devices that provide a chain of links that forms cluster tree of linked devices and networks.

Each of these IoT networks may provide opportunities for new technical features, such as those as described herein. The improved technologies and networks may enable the exponential growth of devices and networks, including the use of IoT networks into as fog devices or systems. As the use of such improved technologies grows, the IoT networks may be developed for self-management, functional evolution, and collaboration, without needing direct human intervention. The improved technologies may even enable IoT networks to function without centralized controlled systems. Accordingly, the improved technologies described herein may be used to automate and enhance network management and operation functions far beyond current implementations.

In an example, communications between IoT devices **104**, such as over the backbone links **102**, may be protected by a decentralized system for authentication, authorization, and accounting (AAA). In a decentralized AAA system, distrib-

uted payment, credit, audit, authorization, and authentication systems may be implemented across interconnected heterogeneous network infrastructure. This allows systems and networks to move towards autonomous operations. In these types of autonomous operations, machines may even contract for human resources and negotiate partnerships with other machine networks. This may allow the achievement of mutual objectives and balanced service delivery against outlined, planned service level agreements as well as achieve solutions that provide metering, measurements, traceability and trackability. The creation of new supply chain structures and methods may enable a multitude of services to be created, mined for value, and collapsed without any human involvement.

Such IoT networks may be further enhanced by the integration of sensing technologies, such as sound, light, electronic traffic, facial and pattern recognition, smell, vibration, into the autonomous organizations among the IoT devices. The integration of sensory systems may allow systematic and autonomous communication and coordination of service delivery against contractual service objectives, orchestration and quality of service (QoS) based swarming and fusion of resources. Some of the individual examples of network-based resource processing include the following.

The mesh network **156**, for instance, may be enhanced by systems that perform inline data-to-information transforms. For example, self-forming chains of processing resources comprising a multi-link network may distribute the transformation of raw data to information in an efficient manner, and the ability to differentiate between assets and resources and the associated management of each. Furthermore, the proper components of infrastructure and resource based trust and service indices may be inserted to improve the data integrity, quality, assurance and deliver a metric of data confidence.

The WLAN network **158**, for instance, may use systems that perform standards conversion to provide multi-standard connectivity, enabling IoT devices **104** using different protocols to communicate. Further systems may provide seamless interconnectivity across a multi-standard infrastructure comprising visible Internet resources and hidden Internet resources.

Communications in the cellular network **160**, for instance, may be enhanced by systems that offload data, extend communications to more remote devices, or both. The LPWA network **162** may include systems that perform non-Internet protocol (IP) to IP interconnections, addressing, and routing. Further, each of the IoT devices **104** may include the appropriate transceiver for wide area communications with that device. Further, each IoT device **104** may include other transceivers for communications using additional protocols and frequencies. This is discussed further with respect to the communication environment and hardware of an IoT processing device depicted in FIGS. **10** and **11**.

Finally, clusters of IoT devices may be equipped to communicate with other IoT devices as well as with a cloud network. This may allow the IoT devices to form an ad-hoc network between the devices, allowing them to function as a single device, which may be termed a fog device. This configuration is discussed further with respect to FIG. **9** below.

FIG. **9** illustrates a cloud computing network in communication with a mesh network of IoT devices (devices **202**) operating as a fog device at the edge of the cloud computing network. The mesh network of IoT devices may be termed a fog **220**, operating at the edge of the cloud **200**. To simplify the diagram, not every IoT device **202** is labeled.

The fog **220** may be considered to be a massively interconnected network wherein a number of IoT devices **202** are in communications with each other, for example, by radio links **222**. As an example, this interconnected network may be facilitated using an interconnect specification released by the Open Connectivity Foundation™ (OCF). This standard allows devices to discover each other and establish communications for interconnects. Other interconnection protocols may also be used, including, for example, the optimized link state routing (OLSR) Protocol, the better approach to mobile ad-hoc networking (B.A.T.M.A.N.) routing protocol, or the OMA Lightweight M2M (LWM2M) protocol, among others.

Three types of IoT devices **202** are shown in this example, gateways **204**, data aggregators **226**, and sensors **228**, although any combinations of IoT devices **202** and functionality may be used. The gateways **204** may be edge devices that provide communications between the cloud **200** and the fog **220**, and may also provide the backend process function for data obtained from sensors **228**, such as motion data, flow data, temperature data, and the like. The data aggregators **226** may collect data from any number of the sensors **228**, and perform the back end processing function for the analysis. The results, raw data, or both may be passed along to the cloud **200** through the gateways **204**. The sensors **228** may be full IoT devices **202**, for example, capable of both collecting data and processing the data. In some cases, the sensors **228** may be more limited in functionality, for example, collecting the data and allowing the data aggregators **226** or gateways **204** to process the data.

Communications from any IoT device **202** may be passed along a convenient path (e.g., a most convenient path) between any of the IoT devices **202** to reach the gateways **204**. In these networks, the number of interconnections provide substantial redundancy, allowing communications to be maintained, even with the loss of a number of IoT devices **202**. Further, the use of a mesh network may allow IoT devices **202** that are very low power or located at a distance from infrastructure to be used, as the range to connect to another IoT device **202** may be much less than the range to connect to the gateways **204**.

The fog **220** provided from these IoT devices **202** may be presented to devices in the cloud **200**, such as a server **206**, as a single device located at the edge of the cloud **200**, e.g., a fog device. In this example, the alerts coming from the fog device may be sent without being identified as coming from a specific IoT device **202** within the fog **220**. In this fashion, the fog **220** may be considered a distributed platform that provides computing and storage resources to perform processing or data-intensive tasks such as data analytics, data aggregation, and machine-learning, among others.

In some examples, the IoT devices **202** may be configured using an imperative programming style, e.g., with each IoT device **202** having a specific function and communication partners. However, the IoT devices **202** forming the fog device may be configured in a declarative programming style, allowing the IoT devices **202** to reconfigure their operations and communications, such as to determine needed resources in response to conditions, queries, and device failures. As an example, a query from a user located at a server **206** about the operations of a subset of equipment monitored by the IoT devices **202** may result in the fog **220** device selecting the IoT devices **202**, such as particular sensors **228**, needed to answer the query. The data from these sensors **228** may then be aggregated and analyzed by

any combination of the sensors **228**, data aggregators **226**, or gateways **204**, before being sent on by the fog **220** device to the server **206** to answer the query. In this example, IoT devices **202** in the fog **220** may select the sensors **228** used based on the query, such as adding data from flow sensors or temperature sensors. Further, if some of the IoT devices **202** are not operational, other IoT devices **202** in the fog **220** device may provide analogous data, if available.

In other examples, the operations and functionality described above with reference to FIGS. **1** to **7** may be embodied by a IoT device machine in the example form of an electronic processing system, within which a set or sequence of instructions may be executed to cause the electronic processing system to perform any one of the methodologies discussed herein, according to an example embodiment. The machine may be an IoT device or an IoT gateway, including a machine embodied by aspects of a personal computer (PC), a tablet PC, a personal digital assistant (PDA), a mobile telephone or smartphone, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine may be depicted and referenced in the example above, such machine shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. Further, these and like examples to a processor-based system shall be taken to include any set of one or more machines that are controlled by or operated by a processor (e.g., a computer) to individually or jointly execute instructions to perform any one or more of the methodologies discussed herein.

FIG. **10** illustrates a drawing of a cloud computing network, or cloud **900**, in communication with a number of Internet of Things (IoT) devices. The cloud **900** may represent the Internet, or may be a local area network (LAN), or a wide area network (WAN), such as a proprietary network for a company. The IoT devices may include any number of different types of devices, grouped in various combinations. For example, a traffic control group **906** may include IoT devices along streets in a city. These IoT devices may include stoplights, traffic flow monitors, cameras, weather sensors, and the like. The traffic control group **906**, or other subgroups, may be in communication with the cloud **900** through wired or wireless links **908**, such as LPWA links, optical links, and the like. Further, a wired or wireless sub-network **912** may allow the IoT devices to communicate with each other, such as through a local area network, a wireless local area network, and the like. The IoT devices may use another device, such as a gateway **910** or **928** to communicate with remote locations such as the cloud **900**; the IoT devices may also use one or more servers **930** to facilitate communication with the cloud **900** or with the gateway **910**. For example, the one or more servers **930** may operate as an intermediate network node to support a local edge cloud or fog implementation among a local area network. Further, the gateway **928** that is depicted may operate in a cloud-to-gateway-to-many edge devices configuration, such as with the various IoT devices **914**, **920**, **924** being constrained or dynamic to an assignment and use of resources in the cloud **900**.

Other example groups of IoT devices may include remote weather stations **914**, local information terminals **916**, alarm systems **918**, automated teller machines **920**, alarm panels **922**, or moving vehicles, such as emergency vehicles **924** or other vehicles **926**, among many others. Each of these IoT devices may be in communication with other IoT devices, with servers **904**, with another IoT fog device or system (not shown, but depicted in FIG. **8**), or a combination therein. The groups of IoT devices may be deployed in various residential, commercial, and industrial settings (including in both private or public environments).

As can be seen from FIG. **10**, a large number of IoT devices may be communicating through the cloud **900**. This may allow different IoT devices to request or provide information to other devices autonomously. For example, a group of IoT devices (e.g., the traffic control group **906**) may request a current weather forecast from a group of remote weather stations **914**, which may provide the forecast without human intervention. Further, an emergency vehicle **924** may be alerted by an automated teller machine **920** that a burglary is in progress. As the emergency vehicle **924** proceeds towards the automated teller machine **920**, it may access the traffic control group **906** to request clearance to the location, for example, by lights turning red to block cross traffic at an intersection in sufficient time for the emergency vehicle **924** to have unimpeded access to the intersection.

Clusters of IoT devices, such as the remote weather stations **914** or the traffic control group **906**, may be equipped to communicate with other IoT devices as well as with the cloud **900**. This may allow the IoT devices to form an ad-hoc network between the devices, allowing them to function as a single device, which may be termed a fog device or system (e.g., as described above with reference to FIG. **8**).

FIG. **11** is a block diagram of an example of components that may be present in an IoT device **1050** for implementing the techniques described herein. The IoT device **1050** may include any combinations of the components shown in the example or referenced in the disclosure above. The components may be implemented as ICs, portions thereof, discrete electronic devices, or other modules, logic, hardware, software, firmware, or a combination thereof adapted in the IoT device **1050**, or as components otherwise incorporated within a chassis of a larger system. Additionally, the block diagram of FIG. **11** is intended to depict a high-level view of components of the IoT device **1050**. However, some of the components shown may be omitted, additional components may be present, and different arrangement of the components shown may occur in other implementations.

The IoT device **1050** may include a processor **1052**, which may be a microprocessor, a multi-core processor, a multithreaded processor, an ultra-low voltage processor, an embedded processor, or other known processing element. The processor **1052** may be a part of a system on a chip (SoC) in which the processor **1052** and other components are formed into a single integrated circuit, or a single package, such as the Edison™ or Galileo™ SoC boards from Intel. As an example, the processor **1052** may include an Intel® Architecture Core™ based processor, such as a Quark™, an Atom™ an i3, an i5, an i7, or an MCU-class processor, or another such processor available from Intel® Corporation, Santa Clara, Calif. However, any number other processors may be used, such as available from Advanced Micro Devices, Inc. (AMD) of Sunnyvale, Calif., a MIPS-based design from MIPS Technologies, Inc. of Sunnyvale, Calif., an ARM-based design licensed from ARM Holdings, Ltd. or customer thereof, or their licensees or adopters. The processors may include units such as an A5-A10 processor from Apple® Inc., a Snapdragon™ processor from Qualcomm® Technologies, Inc., or an OMAP™ processor from Texas Instruments, Inc.

The processor **1052** may communicate with a system memory **1054** over an interconnect **1056** (e.g., a bus). Any

number of memory devices may be used to provide for a given amount of system memory. As examples, the memory may be random access memory (RAM) in accordance with a Joint Electron Devices Engineering Council (JEDEC) design such as the DDR or mobile DDR standards (e.g., LPDDR, LPDDR2, LPDDR3, or LPDDR4). In various implementations the individual memory devices may be of any number of different package types such as single die package (SDP), dual die package (DDP) or quad die package (Q17P). These devices, in some examples, may be directly soldered onto a motherboard to provide a lower profile solution, while in other examples the devices are configured as one or more memory modules that in turn couple to the motherboard by a given connector. Any number of other memory implementations may be used, such as other types of memory modules, e.g., dual inline memory modules (DIMMs) of different varieties including but not limited to microDIMMs or MiniDIMMs.

To provide for persistent storage of information such as data, applications, operating systems and so forth, a storage **1058** may also couple to the processor **1052** via the interconnect **1056**. In an example the storage **1058** may be implemented via a solid state disk drive (SSDD). Other devices that may be used for the storage **1058** include flash memory cards, such as SD cards, microSD cards, xD picture cards, and the like, and USB flash drives. In low power implementations, the storage **1058** may be on-die memory or registers associated with the processor **1052**. However, in some examples, the storage **1058** may be implemented using a micro hard disk drive (HDD). Further, any number of new technologies may be used for the storage **1058** in addition to, or instead of, the technologies described, such resistance change memories, phase change memories, holographic memories, or chemical memories, among others.

The components may communicate over the interconnect **1056**. The interconnect **1056** may include any number of technologies, including industry standard architecture (ISA), extended ISA (EISA), peripheral component interconnect (PCI), peripheral component interconnect extended (PCIx), PCI express (PCIe), or any number of other technologies. The interconnect **1056** may be a proprietary bus, for example, used in a SoC based system. Other bus systems may be included, such as an I2C interface, an SPI interface, point to point interfaces, and a power bus, among others.

The interconnect **1056** may couple the processor **1052** to a mesh transceiver **1062**, for communications with other mesh devices **1064**. The mesh transceiver **1062** may use any number of frequencies and protocols, such as 2.4 Gigahertz (GHz) transmissions under the IEEE 802.15.4 standard, using the Bluetooth® low energy (BLE) standard, as defined by the Bluetooth® Special Interest Group, or the ZigBee® standard, among others. Any number of radios, configured for a particular wireless communication protocol, may be used for the connections to the mesh devices **1064**. For example, a WLAN unit may be used to implement Wi-Fi™ communications in accordance with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard. In addition, wireless wide area communications, e.g., according to a cellular or other wireless wide area protocol, may occur via a WWAN unit.

The mesh transceiver **1062** may communicate using multiple standards or radios for communications at different range. For example, the IoT device **1050** may communicate with close devices, e.g., within about 10 meters, using a local transceiver based on BLE, or another low power radio, to save power. More distant mesh devices **1064**, e.g., within about 50 meters, may be reached over ZigBee or other intermediate power radios. Both communications techniques may take place over a single radio at different power levels, or may take place over separate transceivers, for example, a local transceiver using BLE and a separate mesh transceiver using ZigBee.

A wireless network transceiver **1066** may be included to communicate with devices or services in the cloud **1000** via local or wide area network protocols. The wireless network transceiver **1066** may be a LPWA transceiver that follows the IEEE 802.15.4, or IEEE 802.15.4g standards, among others. The IoT device **1050** may communicate over a wide area using LoRaWAN™ (Long Range Wide Area Network) developed by Semtech and the LoRa Alliance. The techniques described herein are not limited to these technologies, but may be used with any number of other cloud transceivers that implement long range, low bandwidth communications, such as Sigfox, and other technologies. Further, other communications techniques, such as time-slotted channel hopping, described in the IEEE 802.15.4e specification may be used.

Any number of other radio communications and protocols may be used in addition to the systems mentioned for the mesh transceiver **1062** and wireless network transceiver **1066**, as described herein. For example, the radio transceivers **1062** and **1066** may include an LTE or other cellular transceiver that uses spread spectrum (SPA/SAS) communications for implementing high speed communications. Further, any number of other protocols may be used, such as Wi-Fi® networks for medium speed communications and provision of network communications.

The radio transceivers **1062** and **1066** may include radios that are compatible with any number of 3GPP (Third Generation Partnership Project) specifications, notably Long Term Evolution (LTE), Long Term Evolution-Advanced (LTE-A), and Long Term Evolution-Advanced Pro (LTE-A Pro). It can be noted that radios compatible with any number of other fixed, mobile, or satellite communication technologies and standards may be selected. These may include, for example, any Cellular Wide Area radio communication technology, which may include e.g. a 5th Generation (5G) communication systems, a Global System for Mobile Communications (GSM) radio communication technology, a General Packet Radio Service (GPRS) radio communication technology, or an Enhanced Data Rates for GSM Evolution (EDGE) radio communication technology, a UMTS (Universal Mobile Telecommunications System) communication technology, In addition to the standards listed above, any number of satellite uplink technologies may be used for the wireless network transceiver **1066**, including, for example, radios compliant with standards issued by the ITU (International Telecommunication Union), or the ETSI (European Telecommunications Standards Institute), among others. The examples provided herein are thus understood as being applicable to various other communication technologies, both existing and not yet formulated.

A network interface controller (NIC) **1068** may be included to provide a wired communication to the cloud **1000** or to other devices, such as the mesh devices **1064**. The wired communication may provide an Ethernet connection, or may be based on other types of networks, such as Controller Area Network (CAN), Local Interconnect Network (LIN), DeviceNet, ControlNet, Data Highway+, PROFIBUS, or PROFINET, among many others. An additional NIC **1068** may be included to allow connect to a second network, for example, a NIC **1068** providing communica-

tions to the cloud over Ethernet, and a second NIC **1068** providing communications to other devices over another type of network.

The interconnect **1056** may couple the processor **1052** to an external interface **1070** that is used to connect external devices or subsystems. The external devices may include sensors **1072**, such as accelerometers, level sensors, flow sensors, optical light sensors, camera sensors, temperature sensors, a global positioning system (GPS) sensors, pressure sensors, barometric pressure sensors, and the like. The external interface **1070** further may be used to connect the IoT device **1050** to actuators **1074**, such as power switches, valve actuators, an audible sound generator, a visual warning device, and the like.

In some optional examples, various input/output (I/O) devices may be present within, or connected to, the IoT device **1050**. For example, a display or other output device **1084** may be included to show information, such as sensor readings or actuator position. An input device **1086**, such as a touch screen or keypad may be included to accept input. An output device **1084** may include any number of forms of audio or visual display, including simple visual outputs such as binary status indicators (e.g., LEDs) and multi-character visual outputs, or more complex outputs such as display screens (e.g., LCD screens), with the output of characters, graphics, multimedia objects, and the like being generated or produced from the operation of the IoT device **1050**.

A battery **1076** may power the IoT device **1050**, although in examples in which the IoT device **1050** is mounted in a fixed location, it may have a power supply coupled to an electrical grid. The battery **1076** may be a lithium ion battery, or a metal-air battery, such as a zinc-air battery, an aluminum-air battery, a lithium-air battery, and the like.

A battery monitor/charger **1078** may be included in the IoT device **1050** to track the state of charge (SoCh) of the battery **1076**. The battery monitor/charger **1078** may be used to monitor other parameters of the battery **1076** to provide failure predictions, such as the state of health (SoH) and the state of function (SoF) of the battery **1076**. The battery monitor/charger **1078** may include a battery monitoring integrated circuit, such as an LTC4020 or an LTC2990 from Linear Technologies, an ADT7488A from ON Semiconductor of Phoenix Ariz., or an IC from the UCD90xxx family from Texas Instruments of Dallas, Tex. The battery monitor/charger **1078** may communicate the information on the battery **1076** to the processor **1052** over the interconnect **1056**. The battery monitor/charger **1078** may also include an analog-to-digital (ADC) convertor that allows the processor **1052** to directly monitor the voltage of the battery **1076** or the current flow from the battery **1076**. The battery parameters may be used to determine actions that the IoT device **1050** may perform, such as transmission frequency, mesh network operation, sensing frequency, and the like.

A power block **1080**, or other power supply coupled to a grid, may be coupled with the battery monitor/charger **1078** to charge the battery **1076**. In some examples, the power block **1080** may be replaced with a wireless power receiver to obtain the power wirelessly, for example, through a loop antenna in the IoT device **1050**. A wireless battery charging circuit, such as an LTC4020 chip from Linear Technologies of Milpitas, Calif., among others, may be included in the battery monitor/charger **1078**. The specific charging circuits chosen depend on the size of the battery **1076**, and thus, the current required. The charging may be performed using the Airfuel standard promulgated by the Airfuel Alliance, the Qi wireless charging standard promulgated by the Wireless Power Consortium, or the Rezence charging standard, promulgated by the Alliance for Wireless Power, among others.

The storage **1058** may include instructions **1082** in the form of software, firmware, or hardware commands to implement the techniques described herein. Although such instructions **1082** are shown as code blocks included in the memory **1054** and the storage **1058**, it may be understood that any of the code blocks may be replaced with hardwired circuits, for example, built into an application specific integrated circuit (ASIC).

In an example, the instructions **1082** provided via the memory **1054**, the storage **1058**, or the processor **1052** may be embodied as a non-transitory, machine readable medium **1060** including code to direct the processor **1052** to perform electronic operations in the IoT device **1050**. The processor **1052** may access the non-transitory, machine readable medium **1060** over the interconnect **1056**. For instance, the non-transitory, machine readable medium **1060** may be embodied by devices described for the storage **1058** of FIG. **11** or may include specific storage units such as optical disks, flash drives, or any number of other hardware devices. The non-transitory, machine readable medium **1060** may include instructions to direct the processor **1052** to perform a specific sequence or flow of actions, for example, as described with respect to the flowchart(s) and block diagram (s) of operations and functionality depicted above.

In further examples, a machine-readable medium also includes any tangible medium that is capable of storing, encoding or carrying instructions for execution by a machine and that cause the machine to perform any one or more of the methodologies of the present disclosure or that is capable of storing, encoding or carrying data structures utilized by or associated with such instructions. A "machine-readable medium" thus may include, but is not limited to, solid-state memories, and optical and magnetic media. Specific examples of machine-readable media include non-volatile memory, including but not limited to, by way of example, semiconductor memory devices (e.g., electrically programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM)) and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The instructions embodied by a machine-readable medium may further be transmitted or received over a communications network using a transmission medium via a network interface device utilizing any one of a number of transfer protocols (e.g., HTTP).

It should be understood that the functional units or capabilities described in this specification may have been referred to or labeled as components or modules, in order to more particularly emphasize their implementation independence. Such components may be embodied by any number of software or hardware forms. For example, a component or module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A component or module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. Components or modules may also be implemented in software for execution by various types of processors. An identified component or module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified component or module need not

be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the component or module and achieve the stated purpose for the component or module.

Indeed, a component or module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices or processing systems. In particular, some aspects of the described process (such as code rewriting and code analysis) may take place on a different processing system (e.g., in a computer in a data center), than that in which the code is deployed (e.g., in a computer embedded in a sensor or robot). Similarly, operational data may be identified and illustrated herein within components or modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The components or modules may be passive or active, including agents operable to perform desired functions.

Additional examples of the presently described method, system, and device embodiments include the following, non-limiting configurations. Each of the following non-limiting examples may stand on its own, or may be combined in any permutation or combination with any one or more of the other examples provided below or throughout the present disclosure.

ADDITIONAL NOTES AND EXAMPLES

Example 1 may include an electronic processing system, comprising a processor, memory communicatively coupled to the processor, and logic communicatively coupled to the processor to associate an asset to a fixture with a device positioned proximate to the fixture, determine a location of the device, and determine a location of the fixture based on the location of the device.

Example 2 may include the system of Example 1, wherein the logic is further to determine the location of the device based on an indoor position system.

Example 3 may include the system of Example 3, wherein the logic is further to determine the location of the device based on a radio signal associated with the device.

Example 4 may include the system of Example 1, wherein the logic is further to determine if the location of the fixture changed from a prior location of the fixture to a new location.

Example 5 may include the system of Example 4, wherein the logic is further to provide the new location of the fixture to a machine learning application.

Example 6 may include the system of any of Examples 1 to 5, wherein the device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and wherein the fixture is configured to display articles for retail sale.

Example 7 may include the system of Example 1, further comprising an indoor position system to determine the location of the device, the indoor position system including a geometric arrangement with respect to the location of the fixture.

Example 8 may include the system of Example 7, wherein the indoor position system is based on the relative locations of two or more fixtures.

Example 9 may include a semiconductor package apparatus, comprising a substrate, and logic coupled to the substrate, wherein the logic is at least partly implemented in one or more of configurable logic and fixed-functionality hardware logic, the logic coupled to the substrate to associate an asset to a fixture with a device positioned proximate to the fixture, determine a location of the device, and determine a location of the fixture based on the location of the device.

Example 10 may include the apparatus of Example 9, wherein the logic is further to determine the location of the device based on an indoor position system.

Example 11 may include the apparatus of Example 10, wherein the logic is further to determine the location of the device based on a radio signal associated with the device.

Example 12 may include the apparatus of Example 9, wherein the logic is further to determine if the location of the fixture changed from a prior location of the fixture to a new location.

Example 13 may include the apparatus of Example 12, wherein the logic is further to provide the new location of the fixture to a machine learning application.

Example 14 may include the apparatus of any of Examples 9 to 13, wherein the device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and wherein the fixture is configured to display articles for retail sale.

Example 15 may include a method of tracking a fixture, comprising associating an asset to a fixture with a device positioned proximate to the fixture, determining a location of the device, and determining a location of the fixture based on the location of the device.

Example 16 may include the method of Example 15, wherein the logic is further to determining the location of the device based on an indoor position system.

Example 17 may include the method of Example 16, wherein the logic is further to determining the location of the device based on a radio signal associated with the device.

Example 18 may include the method of Example 15, wherein the logic is further to determining if the location of the fixture changed from a prior location of the fixture to a new location.

Example 19 may include the method of Example 18, wherein the logic is further to providing the new location of the fixture to a machine learning application.

Example 20 may include the method of any of Examples 15 to 19, wherein the device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and wherein the fixture is configured to display articles for retail sale.

Example 21 may include at least one computer readable medium, comprising a set of instructions, which when executed by a computing device, cause the computing device to associate an asset to a fixture with a device positioned proximate to the fixture, determine a location of the device, and determine a location of the fixture based on a location of the device.

Example 22 may include the at least one computer readable medium of Example 21, comprising a further set of instructions, which when executed by the computing device, cause the computing device to determine the location of the device based on an indoor position system.

Example 23 may include the at least one computer readable medium of Example 22, comprising a further set of instructions, which when executed by the computing device, cause the computing device to determine the location of the device based on a radio signal associated with the device.

Example 24 may include the at least one computer readable medium of Example 21, comprising a further set of instructions, which when executed by the computing device, cause the computing device to determine if the location of the fixture changed from a prior location of the fixture to a new location.

Example 25 may include the at least one computer readable medium of Example 24, comprising a further set of instructions, which when executed by the computing device, cause the computing device to provide the new location of the fixture to a machine learning application.

Example 26 may include the at least one computer readable medium of any of Examples 21 to 25, wherein the device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and wherein the fixture is configured to display articles for retail sale.

Example 27 may include a fixture tracker apparatus, comprising means for associating an asset to a fixture with a device positioned proximate to the fixture, means for determining a location of the device, and means for determining a location of the fixture based on the location of the device.

Example 28 may include the apparatus of Example 27, wherein the logic is further to means for determining the location of the device based on an indoor position system.

Example 29 may include the apparatus of Example 28, wherein the logic is further to means for determining the location of the device based on a radio signal associated with the device.

Example 30 may include the apparatus of Example 27, wherein the logic is further to means for determining if the location of the fixture changed from a prior location of the fixture to a new location.

Example 31 may include the apparatus of Example 30, wherein the logic is further to means for providing the new location of the fixture to a machine learning application.

Example 32 may include the apparatus of any of Examples 27 to 31, wherein the device includes a handheld radio frequency identification reader having one or more of a WIFI radio and a BLUETOOTH radio, and wherein the fixture is configured to display articles for retail sale.

Embodiments are applicable for use with all types of semiconductor integrated circuit ("IC") chips. Examples of these IC chips include but are not limited to processors, controllers, chipset components, programmable logic arrays (PLAs), memory chips, network chips, systems on chip (SoCs), SSD/NAND controller ASICs, and the like. In addition, in some of the drawings, signal conductor lines are represented with lines. Some may be different, to indicate more constituent signal paths, have a number label, to indicate a number of constituent signal paths, and/or have arrows at one or more ends, to indicate primary information flow direction. This, however, should not be construed in a limiting manner. Rather, such added detail may be used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit. Any represented signal lines, whether or not having additional information, may actually comprise one or more signals that may travel in multiple directions and may be implemented with any suitable type of signal scheme, e.g., digital or analog lines implemented with differential pairs, optical fiber lines, and/or single-ended lines.

Example sizes/models/values/ranges may have been given, although embodiments are not limited to the same. As manufacturing techniques (e.g., photolithography) mature over time, it is expected that devices of smaller size could be manufactured. In addition, well known power/ground connections to IC chips and other components may or may not be shown within the figures, for simplicity of illustration and discussion, and so as not to obscure certain aspects of the embodiments. Further, arrangements may be shown in block diagram form in order to avoid obscuring embodiments, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the embodiment is to be implemented, i.e., such specifics should be well within purview of one skilled in the art. Where specific details (e.g., circuits) are set forth in order to describe example embodiments, it should be apparent to one skilled in the art that embodiments can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

The term "coupled" may be used herein to refer to any type of relationship, direct or indirect, between the components in question, and may apply to electrical, mechanical, fluid, optical, electromagnetic, electromechanical or other connections. In addition, the terms "first", "second", etc. may be used herein only to facilitate discussion, and carry no particular temporal or chronological significance unless otherwise indicated.

As used in this application and in the claims, a list of items joined by the term "one or more of" may mean any combination of the listed terms. For example, the phrase "one or more of A, B, and C" and the phrase "one or more of A, B, or C" both may mean A; B; C; A and B; A and C; B and C; or A, B and C.

Those skilled in the art will appreciate from the foregoing description that the broad techniques of the embodiments can be implemented in a variety of forms. Therefore, while the embodiments have been described in connection with particular examples thereof, the true scope of the embodiments should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification, and following claims.

We claim:

1. An electronic processing system, comprising:
a processor;
memory communicatively coupled to the processor; and
logic communicatively coupled to the processor to:
associate an asset to a fixture with a mobile device positioned proximate to the fixture, wherein the mobile device is to include one or more of a wearable mobile device or a handheld mobile device, and the asset is an article for sale,
determine a location coordinate for the mobile device,
determine a location of the fixture based on a use of the location coordinate for the mobile device as an approximation for the location of the fixture,
determine if the location of the fixture changed from a prior location of the fixture to a new location of the fixture, and
provide the new location of the fixture to a machine learning application.

2. The system of claim **1**, wherein the logic is further to:
determine the location coordinate for the mobile device based on an indoor position system.

3. The system of claim **2**, wherein the logic is further to:
determine the location coordinate for the mobile device based on a radio signal associated with the mobile device.

4. The system of claim **1**, wherein the mobile device includes a handheld radio frequency identification reader

having wireless technology, and wherein the fixture is configured to support and display articles in a retail environment.

5. The system of claim **1**, further comprising:

an indoor position system to determine the location coordinate for the mobile device, the indoor position system including a geometric arrangement with respect to the location of the fixture.

6. The system of claim **5**, wherein the indoor position system is based on the relative locations of two or more fixtures.

7. A semiconductor package apparatus, comprising:

a substrate; and

logic coupled to the substrate, wherein the logic is at least partly implemented in one or more of configurable logic and fixed-functionality hardware logic, the logic coupled to the substrate to:

associate an asset to a fixture with a mobile device positioned proximate to the fixture, wherein the mobile device is to include one or more of a wearable mobile device or a handheld mobile device, and the asset is an article for sale,

determine a location coordinate for the mobile device,

determine a location of the fixture based on a use of the location coordinate for the mobile device as an approximation for the location of the fixture,

determine if the location of the fixture changed from a prior location of the fixture to a new location of the fixture, and

provide the new location of the fixture to a machine learning application.

8. The apparatus of claim **7**, wherein the logic is further to:

determine the location coordinate for the mobile device based on an indoor position system.

9. The apparatus of claim **8**, wherein the logic is further to:

determine the location coordinate for the mobile device based on a radio signal associated with the mobile device.

10. The apparatus of claim **7**, wherein the mobile device includes a handheld radio frequency identification reader having wireless technology, and wherein the fixture is configured to support and display articles in a retail environment.

11. A method of tracking a fixture, comprising:

associating an asset to a fixture with a mobile device positioned proximate to the fixture, wherein the mobile device includes one or more of a wearable mobile device or a handheld mobile device, and the asset is an article for sale;

determining a location coordinate for the mobile device;

determining a location of the fixture based on a use of the location coordinate for the mobile device as an approximation for the location of the fixture;

determine if the location of the fixture changed from a prior location of the fixture to a new location of the fixture; and

provide the new location of the fixture to a machine learning application.

12. The method of claim **11**, further comprising:

determining the location coordinate for the mobile device based on an indoor position system.

13. The method of claim **12**, further comprising:

determining the location coordinate for the mobile device based on a radio signal associated with the mobile device.

14. The method of claim **11**, wherein the mobile device includes a handheld radio frequency identification reader having technology, and wherein the fixture is configured to support and display articles in a retail environment.

15. At least one computer readable medium, comprising a set of instructions, which when executed by a computing device, cause the computing device to:

associate an asset to a fixture with a mobile device positioned proximate to the fixture,

wherein the mobile device is to include one or more of a wearable mobile device or a handheld mobile device, and the asset is an article for sale;

determine a location coordinate for the mobile device;

determine a location of the fixture based on a use of the location coordinate for the mobile device as an approximation for the location of the fixture;

determine if the location of the fixture changed from a prior location of the fixture to a new location of the fixture; and

provide the new location of the fixture to a machine learning application.

16. The at least one computer readable medium of claim **15**, comprising a further set of instructions, which when executed by the computing device, cause the computing device to:

determine the location coordinate for the mobile device based on an indoor position system.

17. The at least one computer readable medium of claim **16**, comprising a further set of instructions, which when executed by the computing device, cause the computing device to:

determine the location coordinate for the mobile device based on a radio signal associated with the mobile device.

18. The at least one computer readable medium of claim **15**, wherein the device includes a handheld radio frequency identification reader having wireless technology, and wherein the fixture is configured to support and display articles in a retail environment.

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